APPENDIX A

IMPLICATIONS OF RECENT SEISMIC HAZARD STUDIES AT LANL

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SUMMARY

A number of studies (Table 1) have been completed in the last two years to address seismic issues at Los Alamos National Laboratory (LANL). These studies have focused on the potential for surface rupture at Technical Area (TA)-55 and TA-3 and the seismic hazard in general. For surface rupture, studies have centered around the mapping of faults in and around specific technical areas. In addition, a probabilistic surface rupture assessment has been completed for TA-3. For the seismic hazard, studies have focused on the earthquake history on the Pajarito fault.

Table 1 – Seismic Hazard Studies

Task	Ref.
1) Stratigraphic Survey for TA-55	1
2) FY97 Pajarito Trench Study	3
3) Probabilistic Surface Rupture Assessment for TA-3	6
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Surface Rupture

The stratigraphic survey (Ref. 1) for TA-55 found no evidence for existing faults. Thus the area is not susceptible to surface rupture from earthquakes.

The stratigraphic survey for TA-3 (Ref. 13) found faults with vertical displacements in the range of 1-10 feet in 1.22 million year old Bandelier tuff in the TA-3 area. The heaviest concentration of these faults is in the southeast corner of TA-3. This concentration is believed to be defining the southern end of the Rendija Canyon fault. The faults found include one under the Chemistry and Metallurgical Research (CMR) Building (Ref. 4) with a vertical offset of approximately 8 feet.

For non-nuclear facilities at TA-3, surface rupture is not a concern based on the probabilistic study (Ref. 6) and Department of Energy (DOE) guidance (Ref. 11). Designing structures systems and components in the TA-3 area to resist the ground motion caused by an earthquake remains the primary concern when considering the seismic hazard. While surface rupture is not a concern for these structures, siting new facilities over faults with significant vertical offsets should not be done.

For the CMR Building, which is a non-reactor nuclear facility as defined by DOE Order 5480.23, the probability of damaging ground displacement is at or beyond the performance goal for the facility. In its current condition, the probability of damaging ground motion is at least 20 times greater than the probability of damage caused by surface rupture. Therefore, the discovery of the fault under the building does not increase the seismic risk at CMR.

The discovery of a fault under the CMR Building has an impact on decisions concerning upgrades and future uses for the facility. From the seismic perspective, the question which needs to be assessed is whether or not it is prudent to upgrade the structure to resist ground motion loads when the probability of damaging surface rupture is near the performance goal level for the facility. While it is possible to upgrade to resist the displacements caused by permanent ground deformation, the upgrade costs would increase substantially. It should be noted that this site would not be considered adequate for a new nuclear facility.

Seismic Hazard

In the last two years, a number of trenches have been excavated to study the earthquake history on the Pajarito fault. Many aspects of the fault had to be assumed when the probabilistic seismic hazard assessment for Los Alamos (Ref. 2) was complete.

From the 1997 trenches (Ref. 3) it has been determined that the most recent event (MRE) on the Pajarito fault occurred about 1,300 to 2,300 years ago. For the trenches excavated in 1998, the results (Ref. 14) show that the MRE is bracketed by the age of the surface soil, 2,000 years, and the youngest buried soil, 12,000 to 20,000 years. While it is possible to infer that the event found in the 1998 trenches is the same as the most recent event the 1997 trenches at about 2,000 years ago, it can not be conclusively stated because of the large uncertainty indicated by the age span associated with the 1998 trenches.

The slip rate range estimated in the 1997 trench study was 0.06 to 0.21 millimeters/year (mm/yr). The slip rate range estimated in the 1998 trench study was 0.07 to 0.13 mm/yr. The slip rate range used in Reference 2 is 0.01 to 0.95 mm/yr. Thus the data collected in the 1997 and 1998 trench studies are within the parameters assumed in the 1995 probabilistic seismic hazard analysis (Ref. 2). Reference 2 is the basis for the LANL earthquake ground motion used in design of new facilities and in the design of upgrades for existing facilities.

The data gathered in these two studies is not sufficient to conclude whether the Pajarito, Rendija Canyon and Guaje Mountain faults operate in unison or independently during large seismic events. The significance of this information is that the multiple scenarios as to the dependency of the three faults used in the calculation of the seismic hazard in Reference 2 continues to be a valid approach.

1.0 INTRODUCTION

Currently, the guiding document for the seismic hazard at the LANL site is "Seismic Hazards Evaluation of the Los Alamos National Laboratory" prepared by Woodward Clyde Federal Services (Ref. 2). Reference 2, issued in 1995, included paleoseismic investigations, subsurface geologic investigations and evaluation of the seismicity recorded by LANL, as well as reviews of the historical record and previous seismic hazard investigations. Ground motion criteria for the design and evaluation of structures, systems and components at LANL are based on this study.

For LANL, the seismic hazard is dominated by the closest sources with the highest likelihood of producing large earthquakes. The Pajarito fault, whose slip rate was estimated to be about 0.1 mm/yr, is the most dominant contributor to the hazard at return periods beyond 1,000 years. Based on minimal information concerning the seismic history on the Pajarito fault, some of the parameters needed for the probabilistic seismic hazard had to be estimated and/or conservatively assumed. In addition, little was known for the potential for surface rupture at specific sites.

In Fiscal Year (FY) 1997, the first two tasks shown in Table 1 were undertaken to better understand the seismic hazard at the Los Alamos National Laboratory (LANL) site. One study was to investigate the possibility of the Rendija Canyon fault extending through TA-55. The other was to investigate seismic history on the Pajarito fault. From preliminary results of these two studies, questions were raised concerning the structural connection of the Pajarito, Rendija Canyon and Guaje Mountain faults, shown in Figure 1, and surface rupture at TA-3. The additional tasks shown in Table 1 were added to help answer these questions.

At TA-55, the study (Ref. 1) found that the Rendija Canyon fault does not run through TA-55 and that the site is free of any observable faulting. The study did find evidence for faulting further to the west, in the vicinity of TA-3. As indicated in Reference 13, a zone of faulting runs south southwest through the eastern part of TA-3 with some cross fault running to the northwest.

On the Pajarito fault, trench studies were conducted to try to estimate when the last event on the fault occurred, to try to estimate recurrence intervals on events for the estimation of slip rates, and to help determine whether or not the Pajarito, Guaje Mountain and Rendija Canyon faults are interdependent. As indicated above, all of these factors were assumed in Reference 2 and physical data is needed to confirm that the assumptions made were valid and conservative. The investigation initiated in FY97 (Ref. 3) has resulted in finding the most recent event on the Pajarito approximately 1,300 – 2,300 years ago and that slip rates were consistent with those assumed in Reference 2. A similar study (Ref. 14) was begun in FY98. The results of this study indicate that the most recent event occurred 2,000 – 20,000 years ago. Although data permit the most recent event to be the same event in both of the two studies, they also allow for different interpretations. The FY98 study agrees with the FY97 study that the slip rate is within the range assumed in Reference 2.

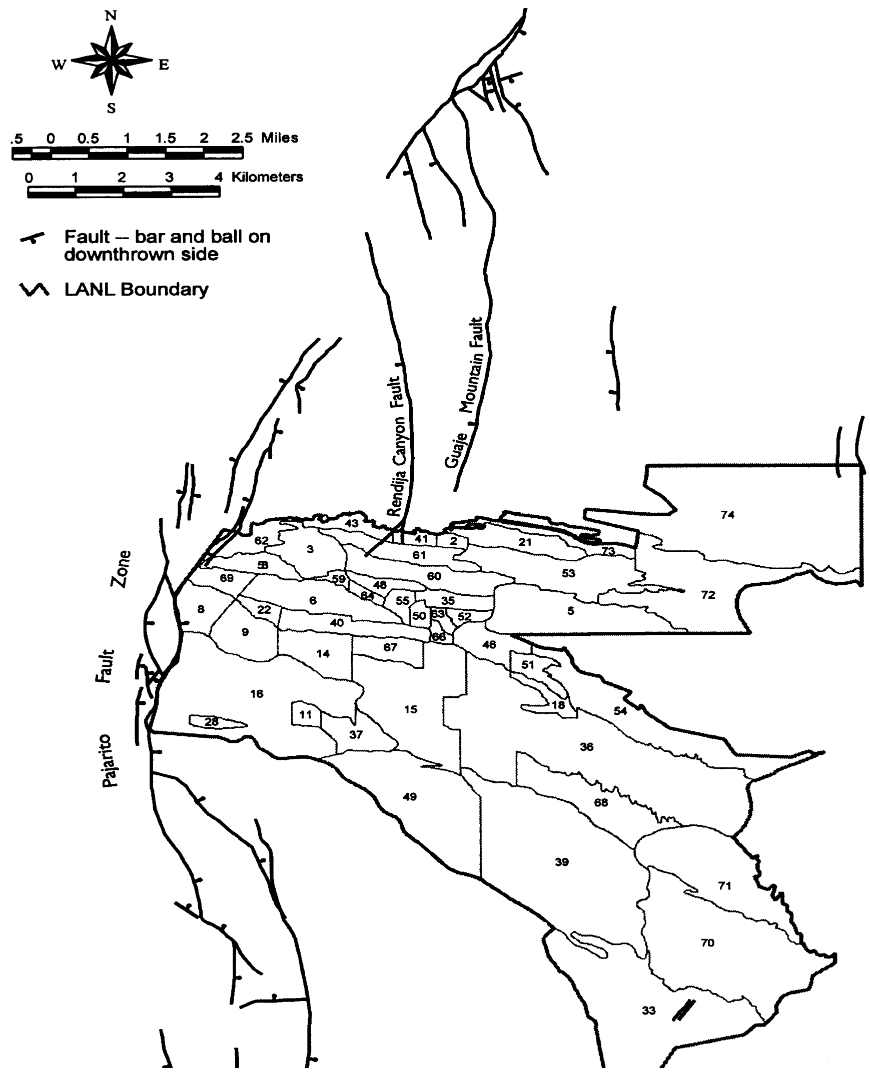

Figure 1 – Major Surface Faults at LANL

In this report, the results of these studies are discussed as well as what the implications are for new and existing construction in TA-3. Findings for individual studies are first presented followed by a summary of DOE seismic requirements. Finally, the impacts on the understanding of the seismic hazard on facilities at LANL, in particular those in TA-3 such as CMR, are presented.

2.0 FINDINGS

The emphasis for work over the last two years falls in two categories: the potential for surface rupture at TA-55 and TA-3, and, investigation of the seismic history on the Pajarito fault.

2.1 Surface Rupture Investigations

Work in this area can be divided into three areas, fault mapping at TA-55 (1st task in Table 1), fault mapping at TA-3 (4th and 5th tasks in Table 1), and probabilistic surface rupture assessment of TA-3 (3rd task in Table 1).

2.1.1 Fault Mapping and Surface Rupture Investigation at TA-55. In Reference 1, results are presented of high-precision geologic mapping in the vicinity of TA-55 that has been done to identify parts of the southern portion of the Rendija Canyon fault, or any other faults, with the potential for seismic surface rupture. To assess the potential for surface rupture at TA-55, an area of approximately 3 square miles that includes the Los Alamos County Landfill and Twomile, Mortandad, and Sandia Canyons has been mapped in detail.

This mapping indicates that there is no faulting in the near surface directly below TA-55, and that the closest fault is about 1500 feet west of the Plutonium Facility. Faulting is more abundant on the western edge of the map area, west of TA-48, near TA-3, in uppermost Mortandad Canyon, upper Sandia Canyon, and at the County Landfill. With the exception of the County Landfill, measured vertical offsets ranged from 1 to 8 feet. At the County Landfill, a distributed zone of faulting over 1000 feet wide with a net down to the west vertical displacement of 30 feet was found. Individual faults within this zone have vertical offsets ranging from 1 to about 15 feet.

2.1.2 Fault Mapping and Surface Rupture Investigation at TA-3. The surface rupture investigation of Reference 1 was expanded to the west to include TA-3. The investigation at TA-3 includes locating and mapping of existing faults using two different methods. One of methods used is high precision mapping employed for the TA-55 study. This method locates the elevations of stratigraphic contacts using total station surveying techniques in exposures around the study area. The other method is the drilling of core holes to locate stratigraphic contacts at specific sites, namely the CMR site (Ref. 4) and the proposed site for the Strategic Computing Center (SCC) and Nonproliferation and International Security Center (NISC) projects (Ref. 5), within TA-3. The entire study of the TA-3 area is documented in Reference 13.

<u>High Precision Mapping at TA-3:</u>

Based on findings presented in Reference 1, the high precision mapping was expanded to include TA-3. The results of this expanded effort are presented in Reference 13. This reference combines the results provided in References 1, 4 and 5 to provide a detailed summary of the faults found from TA-55 to TA-3.

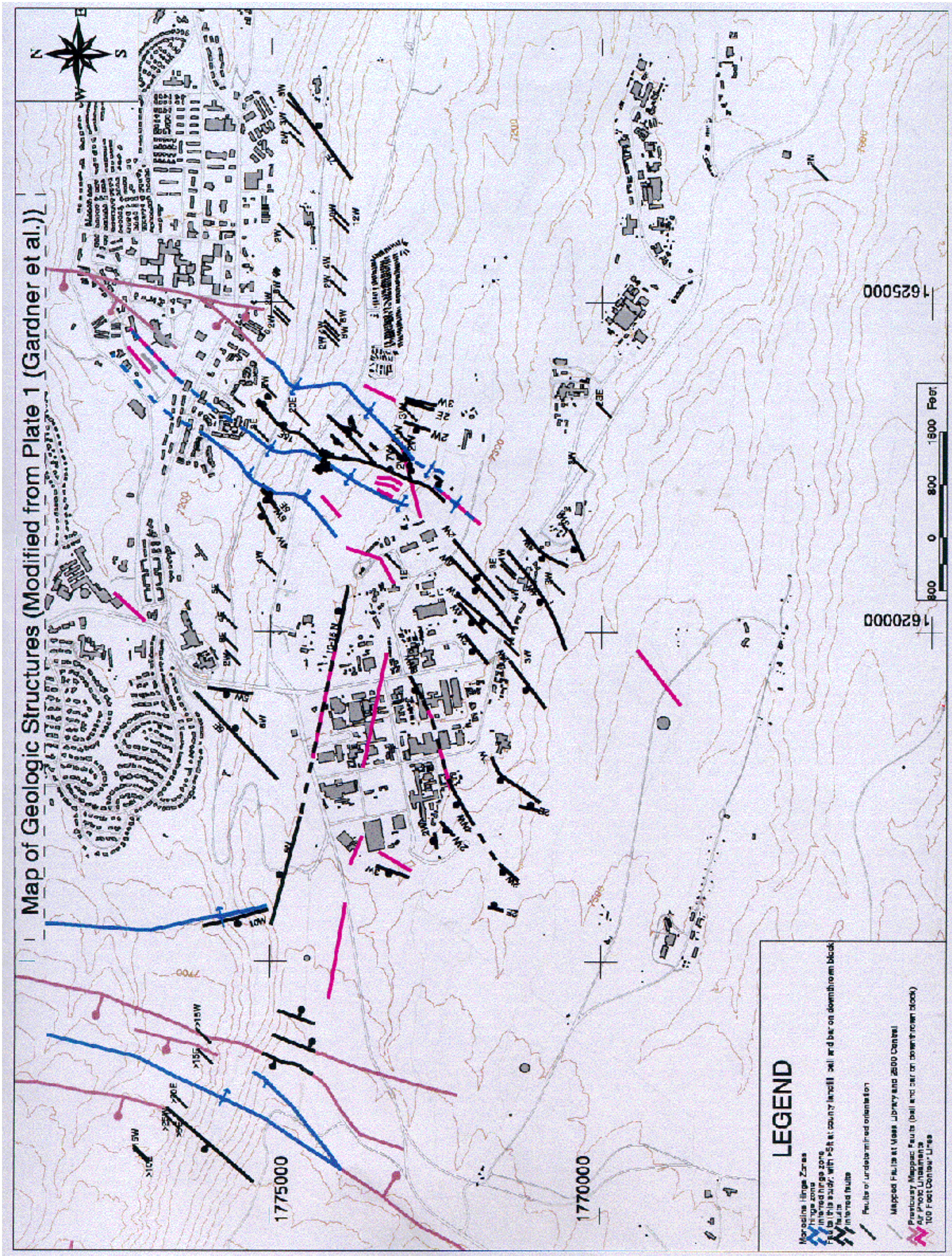

Figure 2 depicts the location faults found from TA-55 to TA-3 along with linear features found in the examination of air photos dating to the 1940's. The majority of the faults found lie in the eastern portion of TA-3, trending toward the southwest. The faults form a zone of vertical deformation which appears to be defining the southern end of the Rendija Canyon fault.

The fault zone increases in width as it progresses southward from approximately 2,000 feet at Los Alamos Canyon at the northern edge of the study to approximately 5,000 feet at Twomile Canyon at the southern edge of the study. The net vertical displacement across the zone as well as the amount of vertical displacement across individual faults gets smaller as the faults extend to the southwest. The net displacements decrease from approximately 100 feet at Los Alamos Canyon to less than 30 feet at Twomile Canyon with individual faults being less than about 10 feet. All of the displacements on these faults occurred over the last 1.22 million years.

The linear features from air photos could indicate linear features such as fences trails and roads but could also indicate the location of faults. These linear features were initially used as guides in the data gathering and analysis portions of this study. As can be seen in the figure, some of the lineaments do coincide with faults found in conjunction with this study, while others are located where no evidence for faulting has been found. It should be noted that the one air photo lineament trending to the northwest through the middle of TA-3 has been identified as a fault on the construction drawings for Buildings TA-3-42 and TA-3-200 but could not be verified in this study.

CMR Core Hole Investigation:

At the site of the existing CMR Building, nine closely spaced, shallow holes were drilled. The purpose of the holes was to obtain the cores and to establish the elevation at which contacts between particular layers of the Bandelier Tuff are located. These elevations were then used to develop a contour map at a particular contact. Abrupt changes in the contours might indicate the presence of faulting. The goal of the investigation was to identify faults that may have the potential for earthquake-induced surface ruptures at the site.

Analysis (Ref. 4) of the data obtained indicates that a fault is present at the CMR Building. Its location and inferred orientation are shown in Figure 3. The fault is contained within the core obtained from the CMR-6 and can be inferred to occur between the CMR-2 and CMR-3 locations. This orientation is consistent with one of the air photo lineaments shown in Figure 2 and faults found in Twomile Canyon (Ref. 13). The total displacement of the faulted stratigraphy in the CMR-6 core is approximately 8 feet in the last 1.22 million years.

Based on this investigation, it can be concluded that the CMR Building site has, in the past, been impacted by fault rupture. However, as discussed later in this report, the probability of an earthquake causing significant surface displacement at this site in the future is small.

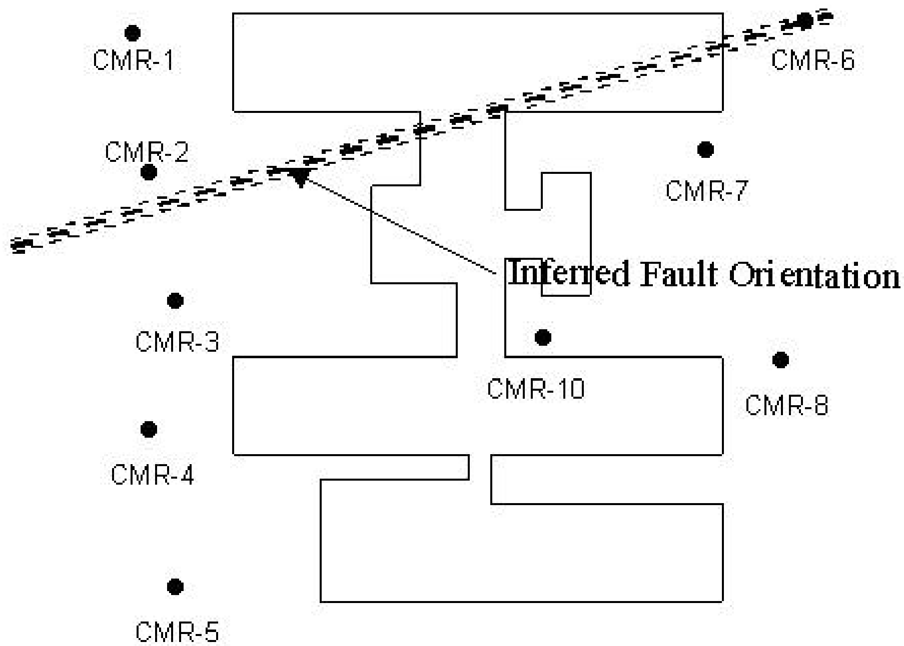

Figure 3 – Plan View of CMR Building with Inferred Location of Fault

<u>SCC/NISC Core Hole Investigation:</u>

At the site proposed for the new Strategic Computing Center (SCC) and the new Nonproliferation and International Security Center (NISC) projects, ten closely spaced, shallow holes were drilled. The purpose of the holes is the same as the holes drilled at the CMR Building.

From analysis (Ref. 5) of the data gathered, there is no evidence for faults under the building sites. Because no significant or cumulative faulting events have disturbed the site in the last 1.22 million years, the age of the Bandelier Tuff, it is unlikely that surface rupture will occur at the site in future large earthquakes.

2.1.3 Probabilistic Surface Rupture Analysis. A probabilistic seismic hazard analysis for potential surface fault displacement at TA-3 has been performed and is described and summarized in Reference 6. The objective of the analysis was to estimate the potential surface rupture hazard posed by the Pajarito fault system, in particular, a possible splay of the Rendija Canyon fault that may transect TA-3. The principal products of this study are probabilistic surface rupture hazard curves for the CMR and SCC/NISC sites. The study focused on these two sites at TA-3 and provides bounding case assessments of the surface rupture potential at each site.

Three different cases were considered in the hazard analysis: (1) distributed faulting only; (2) principal faulting at the CMR site; and, (3) principal faulting at the SCC/NISC site. Principal faulting is faulting occurring along the main plane(s) of crustal weakness responsible for the release of seismic energy during an earthquake. Distributed faulting is defined as rupture that occurs on other faults, shears, or fractures in the vicinity of the principal rupture in response to the principal displacement. The three cases correspond to three different possible scenarios for the southern end of the Rendija Canyon fault. For Case 1, three different hypothetical conditions were assumed: (a) a distributed fault with 9 meters (m) of cumulative displacement in the Bandelier Tuff, (b) a distributed fault with 1 m of cumulative displacement, and (c) a fracture with no observable displacement in the tuff. A total of 15 m of cumulative displacement is assumed in cases 2 and 3.

The results, summarized in Table 2, show that for annual frequencies of 10^{-4} or larger, surface rupture is minimal or nonexistent. The hazard curves developed for the two sites are shown in Figures 4 and 5. Hazard curves that investigate the sensitivity of the three main faults being connected or not are shown in Figure 6.

Table 2 – Probabilistic Surface Rupture Results

Annual Frequency	Case 1a	Case 1b	Case 1c	Case 2&3
10^{-4}	<1 mm	<1 mm	<1 mm	2 cm
10^{-5}	50 cm	20 cm	10 cm	70 cm

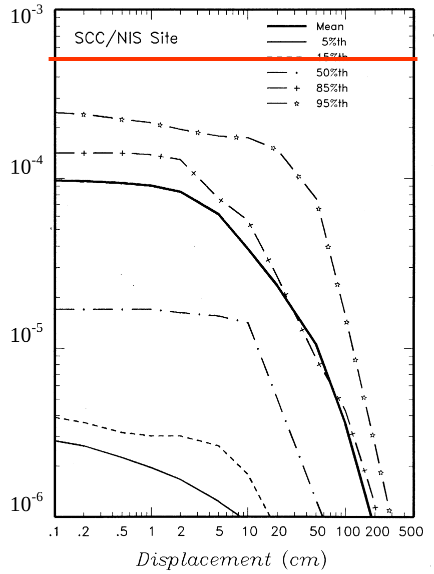

Figure 4a – Case 1a:
Distributed Faulting w/ 9 m
Cumulative Displacement

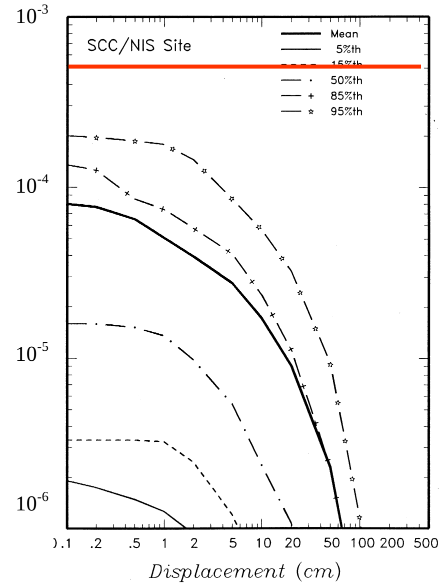

Figure 4b – Case 1b:
Distributed Faulting w/ 1 m
Cumulative Displacement

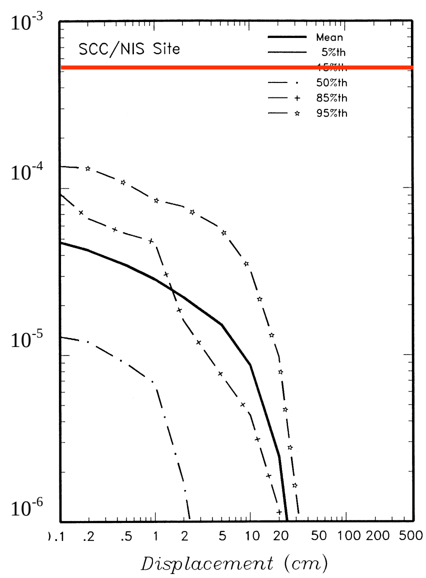

Figure 4c – Case 1c:
Distributed Faulting w/ no
Cumulative Displacement

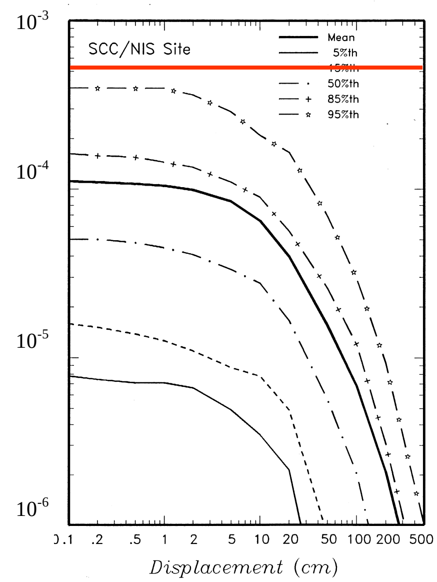

Figure 4d – Case 2:
Principal Faulting w/ 15 m
Cumulative Displacement

Figure 4 – Surface Rupture Hazard Curves for the SCC/NISC Site (Performance Goal for Performance Category (PC) 2 Facilities is $5x10^{-4}$)

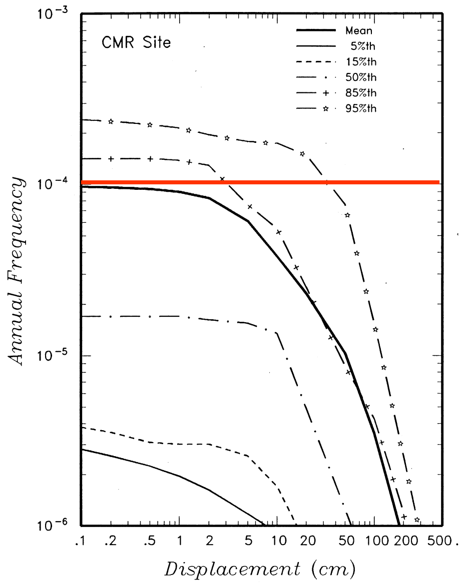

Figure 5a - Case 1a:
Distributed Faulting
9 m Cum. Displacement

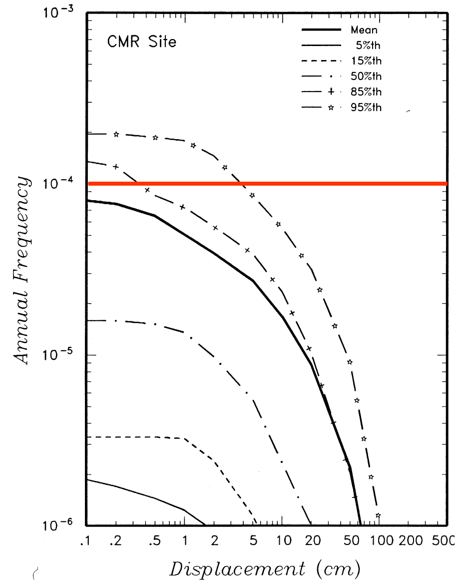

Figure 5b - Case 1b:
Distributed Faulting
1 m Cum. Displacement

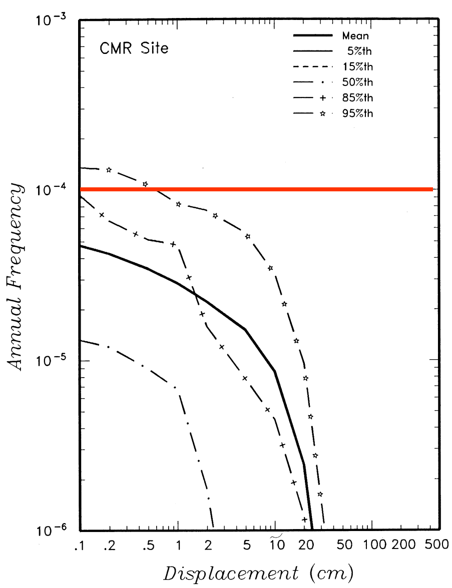

Figure 5c - Case 1c:
Distributed Faulting
No Observable Displacement

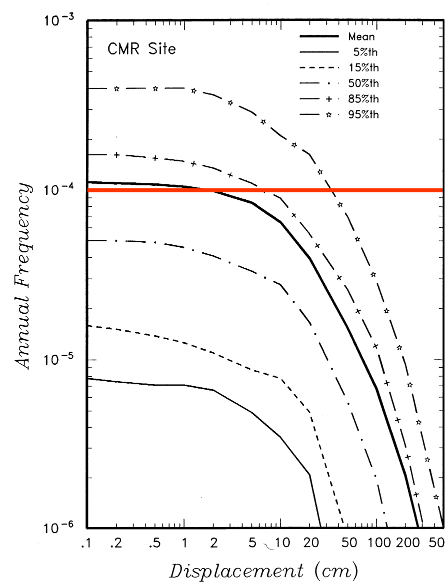

Figure 5d - Case 3:
Principal Faulting
15 m Cum. Displacement

Figure 5 – Surface Rupture Hazard Curves for the CMR Building Site (Performance Goal for Performance Category (PC) 3 Facilities is $1x10^{-4}$)

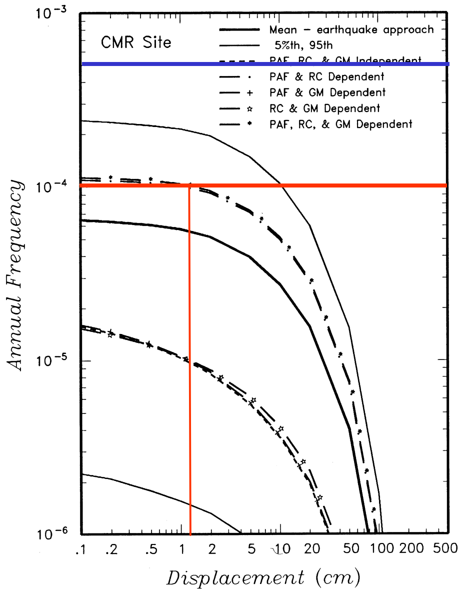

Figure 6a – Case 1b
Distributed Faulting w/ 1 m
Cumulative Displacement

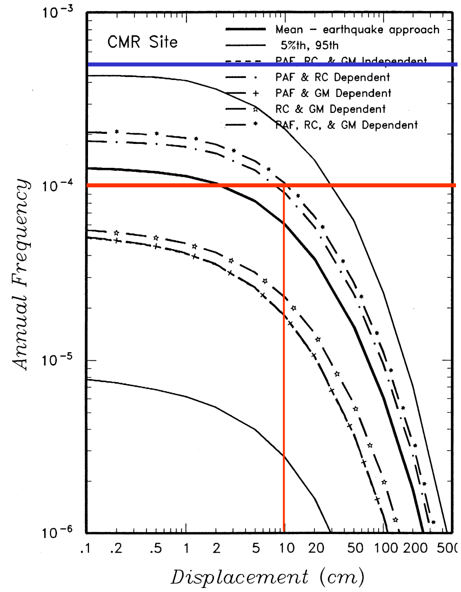

Figure 6b – Case 3:
Principal Faulting w/ 15 m
Cumulative Displacement

Figure 6 – Surface Rupture Hazard Curve Sensitivity Results (Illustrates the Effects of Assuming Fault Dependency on Hazard Curves.)

2.2 Paleoseismic Investigations

Recent paleoseismic investigations have focussed on the Pajarito Fault. Two separate but related studies were initiated in 1997 and 1998. Locations of the studies are shown in Figure 7. Fieldwork for the paleoseismic studies is completed in a fairly short time frame but the analysis of samples required to develop date constraints is a time consuming process.

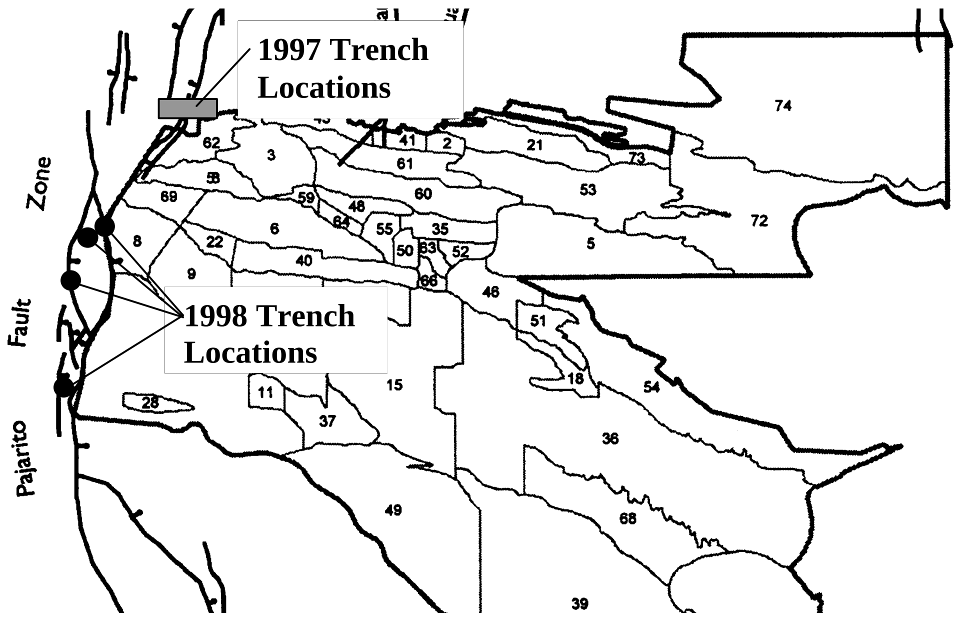

Figure 7 – Locations of Paleoseismic Studies

2.2.1 1997 Paleoseismic Investigation on the Pajarito Fault. In July 1997, seven trenches were excavated across strands of the Pajarito fault zone to characterize the most recent faulting event (MRE), and to refine characterization of previous faulting events. The strategy for capturing the MRE was to excavate a series of seven trenches along an east-west transect across the fault zone south of Los Alamos Canyon, where parallel faults span a zone nearly 2 km wide. Two of the seven trenches were located on the main 50 m high scarp of the Pajarito fault, with the remainder on smaller east- and west-facing scarps. This study is presented in Reference 3.

The best paleoseismic records were preserved on scarps that faced west, or upslope. Each of these trenches displayed evidence of a mid- to late-Holocene MRE. The MRE appears to fall in a relatively narrow age range between about 1300 to 2300 years ago with a likely age of about 1500 years. The net slip rate calculated for the information gathered from these trenches is 0.06 to 0.21 mm/yr.

The MRE, dated at about 1500 years, does not appear to be contemporaneous with the MRE on the Guaje Mountain fault, dated at 4000-6000 years or the MRE on the Rendija Canyon fault, dated at either 8 or 23 thousand years. The trenches on the Pajarito are ambiguous regarding events at either 4000-6000 years or 8000 years. However, it is clear that the 1,500 year event did not rupture the Guaje Mountain or Rendija Canyon faults.

2.2.2 1998 Paleoseismic Investigation on the Pajarito Fault. In June, 1998, seven additional trenches were excavated across the Pajarito fault zone further south than the FY97 study. Again, the purpose of the excavations was to characterize the most recent faulting event (MRE), and to refine characterization of previous faulting events

Four of the trenches did not expose any faults. In the remaining three faults, the MRE falls in a relatively large age range between about 2,000 years, based on the age of the surface soil and 12-20 thousand years based on the age of the uppermost buried soil. The net slip rate calculated for the information gathered from these trenches is 0.07 to 0.13 mm/yr. The MRE in the 1998 trenches could be the same event as the MRE in the 1997 trenches although the broad age range from the 1998 trenches prevents this from being solidly concluded. In addition, the broad age range overlaps with the MRE for the Guaje Mountain fault at 4,000 to 6,000 years and the MRE for the Rendija Canyon fault at 8,000 or 23,000 years.

For both the 1997 and 1998 trenches, there was evidence for only one Holocene (last 10,000 years) earthquake. However, as pointed out in the 1998 report (Ref. 14), the older half of the Holocene (5,000-10,000 years) record was not found in the deposits in the trenches.

3.0 DOE REQUIREMENTS

The DOE, through orders and standards, provides guidance for facility siting and design with respect to earthquakes. The guidance is probabilistically based.

The Implementation Guide to DOE Order 420.1 "Natural Phenomena Hazards for DOE Nuclear Facilities and Non-Nuclear Facilities" (Ref. 7) requires that structures systems and components be designed and constructed to withstand the effects of natural phenomena hazards (NPH) using a graded approach. The target safety levels for structures systems and components (SSCs) subject to NPH are given in the guide in terms of performance goals. These performance goals are defined as the acceptable annual probability of failure. The performance goals are shown in Table 3 and are a function of performance categorization. Performance categorization is determined in accordance with DOE STD 1021 (Ref. 8). The guide also states that siting of structures over active geologic faults should be avoided.

Table 3 – Categories and Performance Goals for SSCs

Performance Category	Description of Performance Required	Seismic Performance Goal (1 yr)
PC0	No consideration.	N/A
PC1	Prevent major structural damage or collapse which would endanger personnel (life-safety).	$1x10^{-3}$
PC2	Maintain operation of essential facilities allowing relatively minor structural damage.	$5x10^{-4}$
PC3	Confinement of hazardous materials.	$1x10^{-4}$
PC4	Confinement of hazardous materials	$1x10^{-5}$

DOE STD 1020 (Ref. 9) specifies seismic loading in probabilistic terms. The annual exceedance probability for the ground motion associated with the various performance categories is shown in Table 4. The peak ground accelerations for LANL are based on the information in Reference 2.

Table 4
Peak Ground Accelerations at LANL

Performance Category	Annual Probability of Exceedance (Return Period)	Horizontal Peak Ground Acceleration (G)	Vertical Peak Ground Acceleration (G)
PC1	$2x10^{-3}$ (500 yr.)	0.15	0.11
PC2	$1x10^{-3}$ (1,000 yr.)	0.22	0.19
PC3	$5x10^{-4}$ (2,000 yr)	0.31	0.27
PC4	$1x10^{-4}$ (10,000 yr)	0.57	0.58

For seismic design, the standard recommends using deterministic design rules that are familiar to design engineers and which have a controlled level of conservatism. This level of conservatism combined with the specification of probabilistic seismic loading leads to performance goal achievement.

DOE STD 1022 (Ref. 10) provides guidance for NPH Characterization Criteria including the necessity for establishing the potential for surface rupture and points to Environmental Protection Agency (EPA) guidance for offsetting hazardous waste facilities from active faults. Active faults are characterized “by the presence of surface or near surface deformation of geologic deposits of a recurring nature within the last approximately 500,000 years or at least one in the last approximately 50,000 years.”

DOE STD 1023 (Ref. 11) provides criteria for NPH assessment. In this document, some guidance is provided for ground failure (surface rupture). If surface rupture may occur near a facility, a probabilistic evaluation may be necessary. If the annual probability of ground failure is greater than the necessary performance goal either the site should be avoided, mitigation measures taken, or an evaluation performed of the effects of fault offset.

4.0 IMPLICATIONS OF FINDINGS

This section discusses the implication of the findings on projects at TA-3 and for the Laboratory in general. These studies have implications for LANL in two areas: (1) surface rupture potential at TA-3 with respect to both non-nuclear facilities and the CMR Building, and (2) design ground motion for all facilities.

4.1 Surface Rupture at TA-3

The studies indicate that there are faults in some locations at TA-3 including under the CMR Building. Based on the seismic history on the primary faults surrounding Los Alamos, these faults are assumed to be “active”. Therefore faults will be addressed in a manner consistent with DOE guidance. For new facilities, building sites should be selected such that significant faults are avoided. For existing facilities that are located over faults the probabilistic approach presented in DOE STD 1023 will be followed.

<u>Non-Nuclear Facilities (PC 1 and PC 2):</u>

For the SCC and NISC projects, a site specific study (Ref. 5) was performed to determine if significant faulting was present at the proposed site. The results of this study indicate the site is clear of faulting and is therefore acceptable for new construction.

For existing facilities, hazard curves developed in the probabilistic surface rupture study (Ref. 6) for TA-3 are used. At the performance goals for PC 1 and PC 2, $1x10^{-3}$ and $5x10^{-4}$, respectively, the estimated displacement for any of the cases as shown in Figures 4 and 5 and summarized in Table 2 is less than 1 millimeter. This is true even for the case where all faults are assumed to be connected. This small amount of displacement has a negligible effect on structures. Therefore, for existing PC 1 and PC 2 facilities, surface rupture is not a credible hazard and the only aspect of the seismic hazard at TA-3 that should be considered is ground motion.

The CMR Building (PC 3)

As previously indicated, it has been determined that there is an existing fault under the CMR. The vertical offset in this fault is approximately 8 feet in the last 1.22 million years. The identification, location and orientation of the fault under the CMR shown in Figure 3 is based on air photo interpretation, high precision mapping of faults in canyons to the south of TA-3, and examination of cores taken from the nine holes drilled around the CMR Building. The air photos indicate a linear feature running through the CMR site from the northeast corner of the facility and through the site to the west-southwest. The high precision mapping effort located a fault with about 5 feet of vertical offset in Twomile Canyon to the southwest which coincides with the southwest end of the air photo feature. The examination of the cores showed that the core taken at the northeast corner (CMR-6) of the facility cut through a fault with a total vertical offset of about 8 feet and that it is likely that the same fault lies between cores CMR-2 and CMR-3. This information also coincides with the air photo feature. The location and orientation of the fault shown in Figure 4 are consistent with the information presented in the referenced studies.

If this site were to be considered for a new nuclear facility, it would not be used and an alternate site, clear of faulting concerns, would be chosen. However, since this is an existing facility, the impact on the safe operation of the facility must be assessed. For this assessment a probabilistic approach is used.

The CMR Building is a PC 3 facility that contains special nuclear materials. The performance goal for design basis earthquakes is $1x10^{-4}$. The vertical offset of the fault under the facility lies between the existing conditions evaluated in cases 1a (9m offset) and 1b (1m offset) in Reference 6. As shown in Table 2, the probable offset for these cases at the performance goal is less than 1 mm. This small amount of displacement has a negligible effect on structures and it could be concluded that the discovery of this fault is not a credible hazard for the design basis event.

However, if the worse case assumption is made that this is a principal fault and that all three faults are connected, the estimated offset from Figure 6 for the PC 3 performance goal is approximately 10 centimeters (4 inches). A displacement of this magnitude can cause significant cracking in a concrete shear wall structure such as those used in the construction of the CMR Building. This cracking could result in a loss of confinement.

It can be shown (Ref. 12) that the annual probability of seismic induced failure, based on ground motion associated with an earthquake, is about $2x10^{-3}$ for most areas of the CMR Building. The exceptions to this is the vault that has an annual probability of seismic induced failure, again, based on ground motion, of about $7x10^{-5}$, and the floor wells which have yet a lower probability of failure. The significance of this information is that ground motion could cause a loss of confinement for most areas of the CMR Building at frequency that is at least 20 times greater than surface rupture.

In the safety analysis for the CMR Building, the consequences of the seismic accident are assessed assuming that the CMR building, with the exception of the vault and floor wells, collapses at the frequency indicated above. With the vault and floor wells located such that they would not be directly effected by surface displacement, the assumptions used in the safety analysis for the seismic accident are still valid even with new knowledge of a fault beneath the facility.

Based on the information from the referenced studies, the fault under the CMR site is a subsidiary fault. As a result, any movement on the fault is likely to be small and would be a result of a large (Magnitude 6 to 7) earthquake on the Rendija Canyon or the Pajarito fault. Such earthquakes are low probability events. In Figure 8 the estimated annual frequency of damage caused by ground motion is compared to the annual frequency of damage caused by surface rupture. This figure illustrates that damaging surface rupture is far less likely to occur than damaging ground motion.

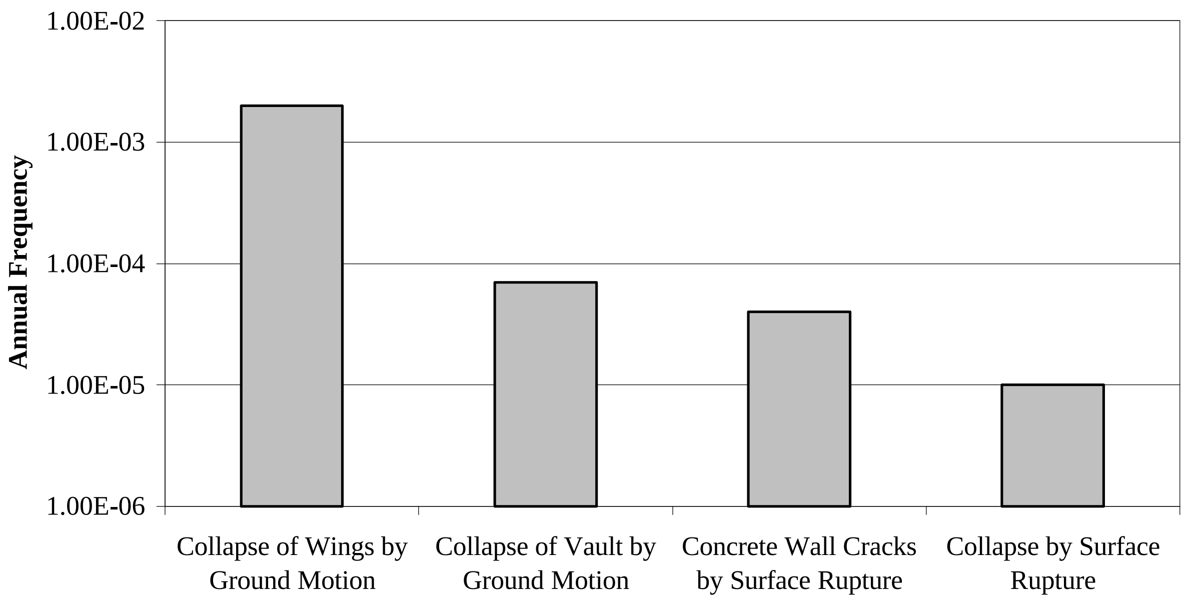

Figure 8 – Frequency of Seismic Induced Damage at CMR Building

4.2 Design Ground Motion

Of the current seismic hazard studies, only the paleoseismic investigations could influence the design ground motion at LANL.

The design ground motion at LANL is based on the results of the probabilistic seismic hazard analysis (PSHA) presented in Reference 2. According to this reference, the net slip rate of the Pajarito fault is the most important input parameter in the PSHA. For this fault the PSHA assumed the slip rates shown in Table 5. One of the objectives of the paleoseismic investigations is to get a more accurate assessment of the slip rate or recurrence intervals on the Pajarito fault.

Table 5 – Net Slip Rates for Pajarito Fault Used In PSHA

Net Slip Rate (mm/yr)	Probability[1]	Percentile[2]
0.01	0.1	5th
0.05	0.2	20th
0.09	0.4	50th
0.20	0.2	80th
0.95	0.1	95th

[1]Probability used in PSHA Logic Tree
[2]Cumulative percentile

Based on the results of the FY97 paleoseismic investigation (Ref. 3) on the Pajarito fault, the net slip rate is 0.06-0.21 mm/yr. From the results of the 1998 study, the net slip rate is 0.07 – 0.13 mm/year. The lower end of the two ranges is less than the median slip rate value of 0.09 mm/yr assumed in the PSHA. The higher end of the two ranges is equal to or less than the 80th percentile motion assumed in PSHA. Therefore, the slip rates calculated in the 1997 and 1998 studies have been bounded by the assumptions made in the PSHA documented in Reference 2. Therefore, the results presented in Reference 2 are still valid for use at the LANL site.

Questions concerning the dependency of the three major faults are based on the physical location and style of deformation of the three faults. Their relative proximity to one another and style of deformation could lead to the conclusion that they must be connected at depth below the earth's surface. However, based on the paleoseismic studies to date, there is no evidence that earthquakes rupture all faults together. The MRE on the Pajarito fault, dated at 1300-2300 years, is not coincident with either the MRE on the Guaje Mountain fault, dated at 4000-6000 years or the MRE on the Rendija Canyon fault, dated at either 8 or 23 thousand years.

Because of the broad age range of the MRE on the 1998 trenches, the data gathered in these two studies are not sufficient to conclude whether or not the Pajarito, Rendija Canyon and Guaje Mountain faults are dependent. The data are sufficient to state that the Pajarito fault can rupture without rupturing the other two based on the MRE on the 1997 trenches and the MRE ages on the other two faults. However, the data are not sufficient to state that one of the other two can rupture without the Pajarito fault also rupturing. The significance of this information is that the logic used to calculate the seismic hazard in Reference 2 is still valid. That study included multiple scenarios as to the dependency of the three faults. Therefore, the results and the methodology of the PSHA are still valid.

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